

The FCC approved two-way service for MMDS in 1998, increasing the functionality and effectiveness of MMDS for providing high-speed data communications services. Licensees have been conducting two-way service trials and are now in the process of rolling out two-way service in selected markets. Sprint Corporation and MCI WorldCom have been actively acquiring MMDS service providers since April 1999. Both companies intend to use MMDS spectrum to provide a "last mile" solution.

MMDS networks have some distinct characteristics compared to networks built in other broadband wireless spectrum. The supercell approach, utilizing a single omni-directional central antenna, can provide MMDS service to an area faster and with a much smaller investment than other broadband services. An MMDS supercell will cover an area of up to 3,850 square miles. This coverage footprint avoids the significant capital expenditures associated with deploying a large number of individual cells for basic coverage purposes and allows the service provider to deploy services to a market very quickly. One carrier has stated that it can erect a supercell and begin to offer service in as little as eight weeks. However, carriers have reported that shadowing, the inability to obtain line-of-sight, can affect as many as 60% of the households in a market depending on the market's physical characteristics.

3.2.2 LMDS

Local Multipoint Distribution Service (LMDS) was created to provide a radio-based delivery service for a wide variety of broadband services. The FCC allocated 1.3 GHz to LMDS in two bands providing sufficient capacity for the service to offer high quality video programming, video conferencing, high-speed data communications and voice telephony. Licensed in the 28 – 31 GHz spectrum band, LMDS can provide one and two-way communications within its spectrum allocation. This is the largest block of spectrum ever authorized by the FCC. The A band is allocated 1,150 MHz and the B band channel is allocated 150 MHz. The Commission believes that this service will provide a viable wireless alternative to incumbent local exchange carriers (ILECs) and cable operators.

With so much spectrum available, LMDS can provide high speed services with data rates reaching 155 Mbit/s. However, due to the high frequency of operation, LMDS requires small cell sizes – on the order of two to three miles in radius. On this basis, the average LMDS cell will cover between 12.6 and 28.3 square miles.

LMDS permits flexible deployment. The carrier can choose to launch its system at a pace to suit its individual business plan without sacrificing quality. The LMDS subscriber will be able to utilize a rooftop or window-based antenna to receive signals from a radio base station.

Nextlink Communications, Inc. is the largest single holder of LMDS spectrum. It acquired WNP Communications, Inc. (the largest spectrum winner in the first FCC LMDS auction) in January 1999. Nextlink was a major auction winner in its own right and now controls 81 LMDS licenses representing 201 million POPs. Nextlink will use its LMDS licenses to connect off-network buildings to the company's fiber optic backbone facilities. Nextlink has not built or launched any of its wireless licenses at this point.

LMDS equipment is now on the market. Manufacturers are offering network systems that can provide up to 99.999% availability. Nextlink plans to conduct infrastructure equipment trials with an infrastructure

vendor in the fourth quarter of 1999. The company indicated that it plans to launch LMDS services in twenty-five of its licensed markets by the end of the fourth quarter of 2000.

At this time, Speedus.com, Inc. (formerly CellularVision) is the only LMDS offering an LMDS-based service on a commercial basis in the top 50 MSAs in the U.S. Speedus.com is licensed to provide LMDS service in the New York PMSA. Other LMDS licensees are working to deploy their networks in other markets across the U.S.

3.2.3 DEMS

The Digital Electronic Messaging Service (DEMS) band is located in the 24 GHz spectrum band. Like the LMDS bands, the DEMS band requires a cell radius of approximately two to three miles (meaning that each cell will cover between a 12.6 and 28.3 square miles). A large amount of cellularization is required to cover a large geographical area. At the current time, Teligent Inc. is the only company licensed to operate in the DEMS band. The service offerings and serving plan are analogous to the LMDS platform.

Teligent has begun offering services in a number of its markets. The company offers a full complement of voice and data communications offerings with data rates ranging to 1.54 Mbit/s. Teligent has deployed telecommunications services in 28 of its 74 licensed markets. The company expects to offer its services in 40 markets by the end of 1999, serving an aggregate population of 100 million people.

3.2.4 38 GHz Band Services

The spectrum around 38 GHz is known as the microwave band. Propagation characteristics in the 38 GHz band require cell sizes even less than that of LMDS and DEMS—approximately 1 mile in radius, with an area of 3.14 square miles.

The 38 GHz band is licensed primarily to two companies: WinStar Communications, Inc. and Advanced Radio Telecom Corp. (ART).

WinStar uses its broadband wireless spectrum in the 38 GHz spectrum band to provide local exchange services, long distance, high-speed data communications and Internet access services primarily to business customers. WinStar holds spectrum licenses in 59 of the top 60 MSAs in the U.S. These markets represent more than 200 million people.

WinStar currently offers services in 30 U.S. markets. The company offers these services on both a bundled and unbundled basis. WinStar expects to offer its services in 45 U.S. markets by the end of 1999 and to deploy its telecommunications network in an additional 15 U.S. markets by the end of 2000 for a total of 60 U.S. markets overall.

ART intends to become the leading provider of broadband Internet access and data communications services and does not intend to concentrate on voice oriented services. ART will use its extensive broadband wireless spectrum in the 38 MHz spectrum band to provide a variety of high-speed data communications and Internet access services to small, medium and large sized business customers.

ART holds spectrum licenses in 210 U.S. markets, including 49 of the top 50 and 90 of the 100 most heavily populated market areas.

ART now offers its data communications services in three of its licensed markets. The company expects to launch its services in 40 markets within the next two years and offer services in up to 100 markets within five years.

3.2.5 Progress in Spectrum Licensing

The FCC has completed licensing for LMDS and MMDS bands. An initial licensee (Teligent) is operating in the DEMS band. The Commission has not scheduled additional licensing activities for these bands at this time.

The FCC has proposed additional broadband wireless services in the 39 GHz band. The auction for this spectrum is scheduled to begin in the second quarter of 2000. The Commission will offer 100 MHz licenses to provide fixed point-to-point and point-to-multipoint broadband telecommunications services.

3.3 Rollout Status

WBA service is concentrated in the Top 50 MSA markets. That's not remarkable, since more than 48% of the U.S. population lives in the Top 50 markets. Service status of the Top 50 MSAs is summarized in the following table outlining rollout status for LMDS, DFMS, 38 GHz and selected MMDS licensees.

Activity Status of Wireless Broadband Access Services in the Top 50 MSA Markets

MSA/NECMA	38 GH	DEMS	MMDS	LMDS	MSA/NECMA	38 GH	DEMS	MMDS	LMDS
Los Angeles – Long Beach, CA	Yes	Yes			Denver, CO	Yes	Yes	Yes	
New York, NY	Yes	Yes	Yes	Yes	Portland – Vancouver, OR WA			Yes	
Chicago, IL	Yes	Yes			Kansas City, MO	Yes			
Boston – Worcester, Lawrence – Lowell – Brockton, MA NH	Yes	Yes	Yes		San Francisco, CA	Yes	Yes		
Philadelphia, PA	Yes	Yes			New Haven B.port Stamford – Danbury- Waterbury, CT	Yes			
Washington, DC	Yes	Yes			Cincinnati, OH				
Detroit, MI	Yes		Yes		San Jose, CA		Yes		
Houston, TX	Yes	Yes			Norfolk – Virginia Beach – Newport News, VA				
Atlanta, GA	Yes	Yes			Ft. Worth – Arlington, TX	Yes		Yes	
Dallas, TX	Yes	Yes	Yes		San Antonio, TX		Yes		
Riverside – San Bernardino, CA					Indianapolis, IN				
Minneapolis – St. Paul, MN	Yes				Sacramento, CA		Yes		
Phoenix – Mesa, AZ	Yes		Yes		Milwaukee, WI	Yes	Yes		
San Diego, CA	Yes	Yes			Columbus, OH	Yes			
Nassau – Suffolk, NY					Orlando, FL		Yes		
Orange County, CA	Yes				Ft. Lauderdale, FL				
St. Louis, MO	Yes				Charlotte – Gastonia – Rock Hill, NC				
Baltimore, MD	Yes	Yes			New Orleans, LA		Yes		
Pittsburgh, PA					Bergen – Passaic, NJ				
Cleveland – Lorain – Elyria, OH	Yes	Yes			Salt Lake City – Ogden, UT				
Oakland, CA	Yes				Las Vegas, NV				
Seattle – Bellevue – Everett, WA	Yes	Yes			Buffalo – Niagara Falls, NY				
Tampa – St. Petersburg – Clearwater, FL	Yes	Yes			Greensboro – Winston-Salem – High Point, NC				
Miami, FL	Yes	Yes			Nashville, TN				
Newark, NJ	Yes				Hartford, CT				

The following points are worthy of note:

- Overall, WBA services are represented in 22 of the 25 largest MSA and 35 of the Top 50 MSA markets.
- 38 GHz has the largest market representation with 29 markets in operation. DEMS has representation in 23 Top 50 markets, with LMDS represented in only one market.
- MMDS carriers provide broadband access services in 8 markets. We counted only those markets where four of the major MMDS carriers (CAI Wireless, CS Wireless, People's Choice TV and American Telecasting) provide data communications services. These carriers have significant television distribution businesses in 67 markets located in various parts of the U.S.

Operational WBA services in markets 51 to 100 are summarized in the following table.

Activity Status of Wireless Broadband Access Services in the MSA Markets 51-100

MSA/NECMA	38 GH	DEMS	MMDS	LMDS
Rochester, NY			Yes	
Austin-San Marcos, TX		Yes		
West Palm Beach – Boca Raton, FL		Yes		
Jacksonville, FL		Yes		
Richmond-Petersburg, VA		Yes		
Wilmington-Newark, DE		Yes		
Colorado Springs, CO			Yes	

- Overall, WBA services are represented in 7 MSAs of this group.
- DEMS was active in 5 of the 7 MSAs and MMDS was active in two.
- 38 GHz and LMDS had no active presence in this second tier grouping.

4.0 Wireline Broadband Access

4.1 Fiber Optic Cable

Fiber optic infrastructure represents the state-of-the-art in terms of broadband communications. Inter-exchange carriers (IXCs) rely on fiber to move large amounts of voice and data traffic between major nodes on their backbone networks. Fiber is widely deployed in:

- Rings around cities and other key commercial areas where communications traffic is particularly heavy; and
- Trunking between network hubs.

Improvements in fiber optic cable's capacity, related to technical advances like dense wavelength division multiplexing (DWDM) technology, allow carriers to move traffic at speeds of 2.4 Gbit/s and higher.

The key to the local exchange business continues to be access to the end users, both business and residential customers. The barrier for fiber optic cable in the local loop continues to be one of access to pre-existing rights-of-way to bridge the "last mile" to the end user. Carriers seeking to install fiber in urban markets face reluctant municipal government, restrictive laws and high costs associated with constructing new underground conduit. Average deployment costs of \$150,000 to \$200,000 per mile makes fiber optic capabilities at the local loop level an expensive undertaking. In urban environments the cost is even higher. Advanced Radio Telecom (ART) estimates the cost of fiber deployment at \$1 million per mile in Seattle and \$3 million per mile in New York City. Even so, carriers are willing to foot that bill on a selective basis where the revenue opportunity justifies the large investment.

Many multi-tenant commercial buildings and multiple dwelling unit (MDU) residential buildings in major urban areas just can't support the traffic levels needed to justify the major up-front investment required to make fiber optic access economically feasible from a carrier's perspective. This is evidenced in the current penetration of fiber to businesses, as detailed in *Telecommunications* magazine:

*"While the competitive local exchange carriers in the U.S. have built out over 50,000 network route miles of fiber, they have fewer than 25,000 buildings on fiber (networks). Out of 1.1 million commercial buildings in the U.S. greater than 10,000 square feet, fiber service achieves only 3% penetration."*⁷

Based on this limitation, fiber optic technology is unlikely to be a major factor in providing broadband communications services to small and medium enterprises and residential end users.

4.2 Hybrid Fiber Coax Cable

Hybrid Fiber Coax (HFC) cable is the broadband communications solution being promoted by the cable TV (CATV) industry. The CATV industry has been using its existing cable plant as a platform for providing broadband data communications services. With an estimated 105 million homes in North America passed by CATV plant and an estimated 75 million subscribers, data communications represents a logical extension of the traditional CATV service menu.

However, most CATV systems were built as one-way pipelines to deliver a selection of entertainment options, primarily to households. CATV plant must be upgraded to support two-way service. The required investment associated with upgrading cable plant to provide two-way service is estimated at \$200 to \$250 per home passed (or \$14 to \$18 billion for the balance of the U.S.).

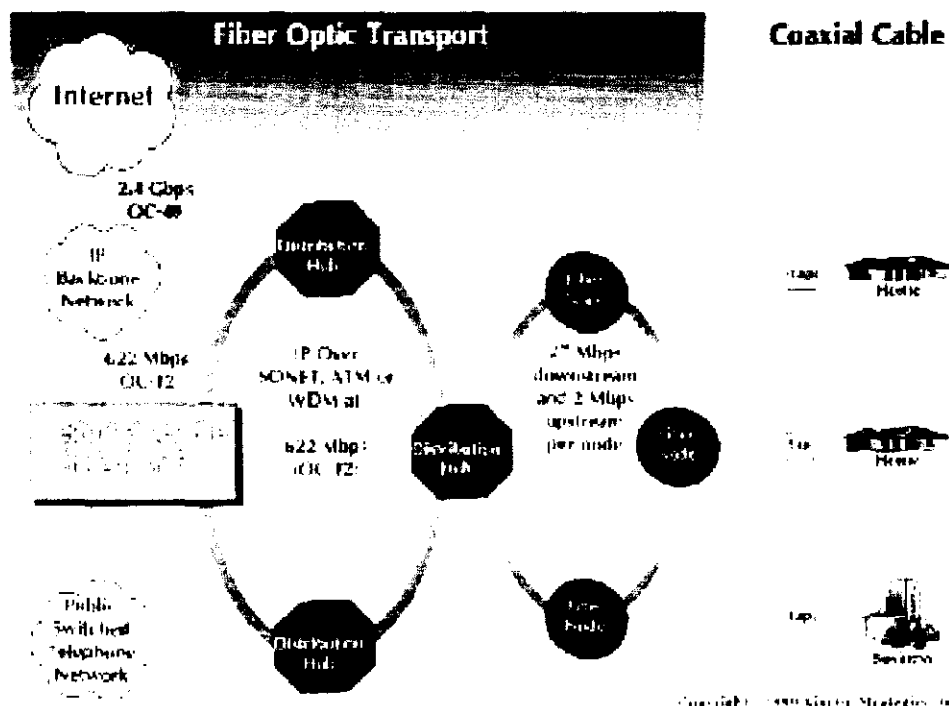
To deliver two-way data services via cable, one cable channel is allocated to carry downstream traffic from the service provider to subscribers and a second is allocated to carry upstream traffic from subscribers to the service provider. The cable system headend communicates through these channels with cable modems located on the subscriber's premises to create

⁷ Suresh Arora and Alike Nagpaul, "Broadband Wireless Solutions for Global Business", *Telecommunications Magazine*, September 1998

a virtual Ethernet-based local area network (LAN). Cable modems are always online with the network.

The downstream channel can be configured to support up to 27 Mbit/s of traffic to the subscriber. The upstream channel may be configured to support from 500 Kbit/s to 10 Mbit/s. This bandwidth is shared by all of the subscribers operating in that network segment, so individual subscribers are not allocated predetermined slices of capacity with pre-agreed throughput levels. Instead, HFC network resources are allocated to subscribers sending or receiving traffic for a fraction of a second and then released for use by other subscribers. Individual users may experience effective downstream rates of between 1 Mbit/s to 3 Mbit/s. Upstream users are likely to experience rates between 500 Kbit/s and 2.5 Mbit/s. Subscribers in congested networks may experience significantly lower access rates.

Hybrid Fiber Coax (HFC) Architecture



The industry has put a great deal of effort into establishing a body of standards including the Open Cable Initiative, the Media Cable Network System (MCNS) and the Data over Cable Service Interface Specifications (DOCSIS) that assured that network equipment and CPE would be interoperable.

The outlook for cable modem service pricing reflects the incremental nature of this business to the cable MSO. Monthly rates of \$40-\$60, including cable modem rental and unlimited Internet access, are the norm.

Cable companies, with their established presence in residential areas, are well positioned to offer broadband communications services to residential subscribers and to businesses which happen to be located in areas served by existing CATV plant. Potential customers located in densely populated urban areas may well be faced with the same "last mile" problem posed by fiber optic systems, with CATV operators reluctant to pay the steep costs associated with developing new rights-of-way in densely populated areas.

At the end of July 1999, there were an estimated 1.1 million cable modem customers in North America and cable modem service was available to an estimated 32 million homes. This represents a penetration rate of 3.4%. Of these subscribers, approximately 800,000 are U.S. subscribers and the balance are Canadian.⁸

4.3 Digital Subscriber Line (DSL)

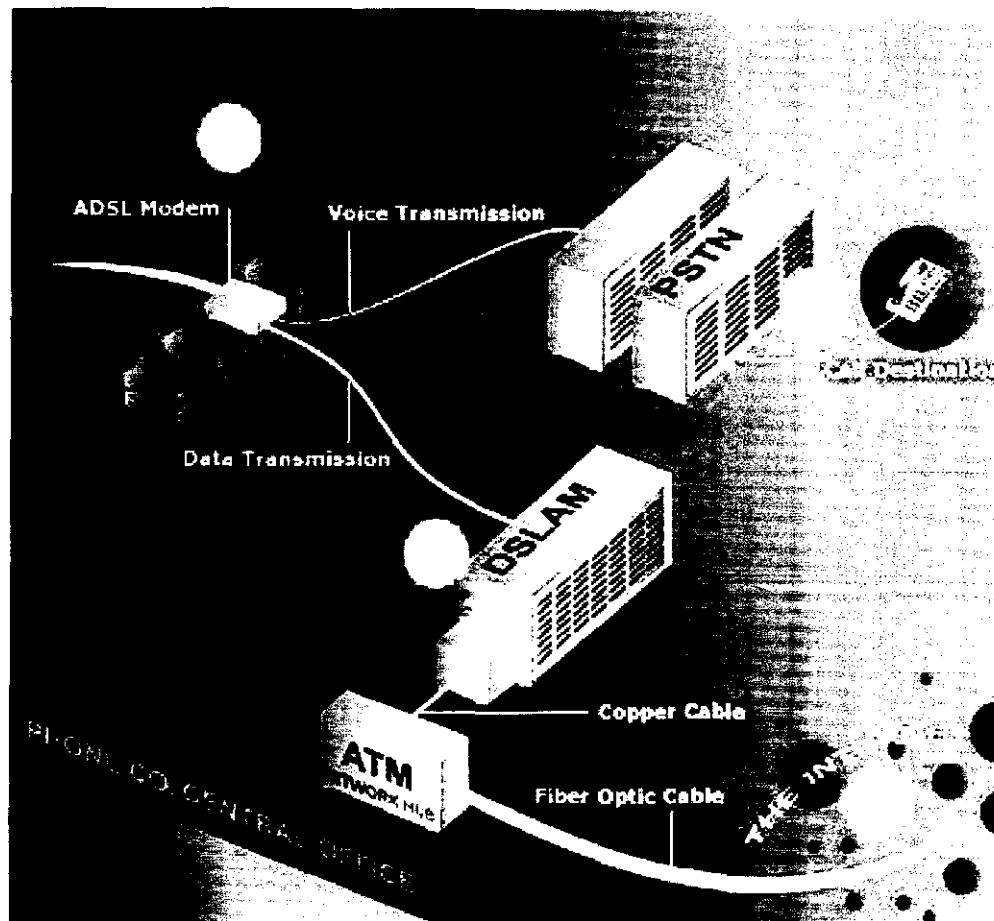
Telecommunications carriers are generally embracing Digital Subscriber Line (DSL) offerings for providing broadband telecommunications services. DSL offers the ability for carriers to provide high-speed digital services over existing copper twisted pair infrastructure. Like cable modems, DSL provides a constant connection to the network.

DSL services will use a digital modem to move voice and data at high speeds along twisted copper pair wiring to a central office. At the central

⁸ Source: Cable Datacom News

office, a splitter routes the data to a digital subscriber line access multiplexer (DSLAM), which delivers the traffic to a high speed backbone connected to the Internet or to a corporate network. Voice traffic is routed to the PSTN.

ADSL Setup at the Central Office



Source: ZDnet.com

DSL is actually a second attempt by the telecom industry to provide a high-speed digital service for its customers. Integrated Services Digital Network (ISDN) was intended to provide better voice quality, higher speed access to data than POTS and a higher level of utility from a single line. ISDN provides data access at 128 Kbit/s, while "broadband" is defined as speeds of 200 Kbit/s and above.

Yet ISDN had a relatively poor reception from customers. ISDN was difficult to install and was relatively expensive. Today, ISDN accounts for about 2.9 million access lines, a small portion of the total access lines in service. While it continues to be available, ISDN services will be eclipsed by higher value alternatives. DSL will provide easier installation, greater bandwidth and lower prices than ISDN services.

Unlike other approaches to broadband, DSL avoids the need for carriers to invest heavily in new rights-of-way or infrastructure, since twisted copper pair is already available in the local loop. Several types of DSL service have been developed and are in the trial stage or in the process of being launched. Some of the versions that are more likely to be widely adopted are summarized in the following table.

Selected DSL Versions

Type	Data Rate	Distance Limits	Other
Asymmetric Digital Subscriber Line (ADSL)	1.544 to 6.1 Mbit/s downstream; 16 to 640 Kbit/s upstream	Maximum of 18,000 feet from the CO.	• Data rates improve for connections made closer to the CO.
ADSL Lite (G.Lite)	1.544 to 6.1 Mbit/s downstream and 384 to 512 Kbit/s upstream	Maximum of 18,000 feet from the CO on 24 gauge wire.	• Compaq, Microsoft and Intel are supporting this version. • Does not require a splitter at the subscriber's site, meaning simpler installation.
High bit rate Digital Subscriber Line (HDSL)	1.544 Mbit/s duplex on twisted pair ; 2.048 Mbit/s duplex on three twisted pair line	12,000 feet on 24 gauge wire	

Note: Full rate ADSL can support up to 8.4 Mbit/s up to 9,000 ft.

Despite its advantages, DSL has two major disadvantages:

- DSL is sensitive to distance. DSL will operate at a maximum of 18,000 feet in a direct path from a DSL-equipped central office.
- Unfortunately, not all central offices can support digital services. Currently, DSL lines cannot be deployed in circumstances where

the copper loop from the telephone central office is not continuous. DSL does not work well with load coils, digital loop carriers (DLCs) and bridge taps. All of these types of equipment have already been deployed in the PSTN to solve other problems.

These problems have delayed the launch of DSL services in most areas of the U.S. For example, some observers have estimated that as many as 40% of all U.S. access lines incorporate DLCs. Mitigating these problems may prove to be a difficult and expensive undertaking.

INSIGHT expects that DSL services will be a logical choice for SMEs and for residential users. Yet the significant constraints associated with distance and existing network impediments mean that DSL services will not be available to all that want them in the next few years.

5.0 WBA Service Advantages

WBA offers significant advantages over other broadband service options.

WBA Service Advantages

Rapid Deployment	WBA technology can be deployed very quickly to end users with service quality comparable to fiber optic networks. An MMDS network based on a supercell design can be deployed in as little as eight weeks. An additional antenna can be added to an LMDS network in as little as two hours. This compares favorably to the substantial delays associated with constructing and provisioning wireline network alternatives.
Community & Environmentally Friendly	Wireless technologies involve a minimal amount of disruption to the community and the environment. Unlike new fiber optic cable and HFC networks, WBA avoids the need for trenching and conduit construction associated with new rights-of-way for traditional wireline access networks.
Flexible Deployment	WBA infrastructure is highly scalable. Unlike mobile wireless services, WBA need not offer ubiquitous network coverage. Coverage can expand as demand increases. WBA can be targeted to serve a specific area or cluster of sites. This simplifies deployment and allows the carrier to expand its network as demand grows. WBA's flexibility will allow network elements to be redeployed if customers relocate or needs change.
Inexpensive	Deployment costs for WBA are less than wireline alternatives for new network deployment, particularly when new rights-of-way must be obtained. A wireless hub may require an investment of \$500,000, but the hub can serve users in an area ranging from 3 square miles for 38 GHz to 3,850 square miles for MMDS. Service prices for WBA are expected to be on a par with wireline offerings. WinStar and Teligent, companies with the widest deployments to date, have offered attractive pricing promotions to tempt new customers.

WBA services will compete directly with wireline service providers in a number of geographic service areas. The development of WBA services should help to alleviate some of the congestion on the PSTN, particularly with regard to Internet access. Yet INSIGHT expects the impact of WBA

services on the established wireline incumbents will be small, relative to the total U.S. telecommunications market opportunity.

Despite the fact that the initial competitive impact of wireless broadband access services will be limited in terms of market share, INSIGHT believes that the benefits of competition associated with lower prices and improved services for the potential users of broadband telecommunications services are real. We also believe that competition will result in the development of new and more innovative services where none would have existed otherwise.

Future wireless broadband applications are likely to include other features that emphasize the wireless network's flexibility. Equipment manufacturers and service providers are talking about delivering real time Bandwidth on Demand (BoD) and voice over Internet Protocol (VoIP) functionality.

Wireless technologies offering fiber-like capabilities can successfully solve the "last mile" problems associated with wireline broadband topologies. The following table outlines some of the wireless advantages relative to other service plans.

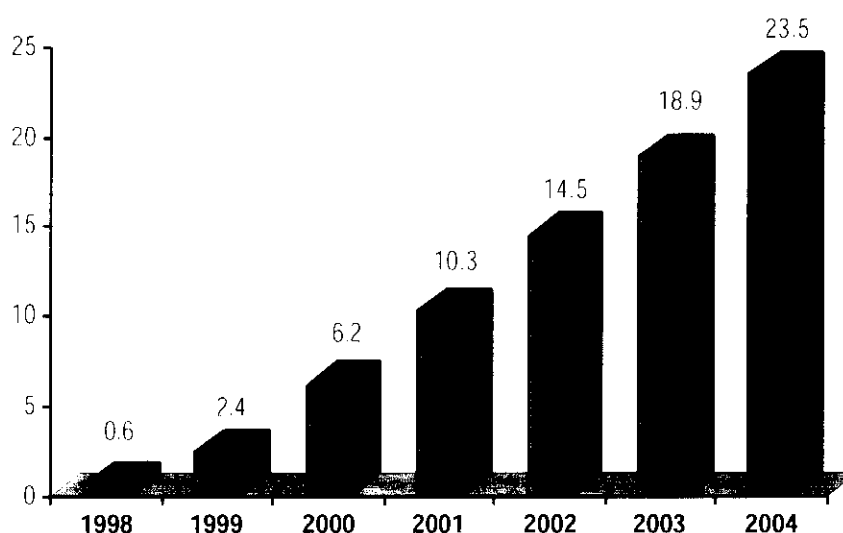
WBA "Last Mile" Advantages

Media	Wireline Broadband Access Problem	Wireless Broadband Access Answer
Fiber Optic Cable	Where high deployment costs make only a small number of MDUs and multi-tenant buildings suitable for fiber optic network builds...	...Fast, flexible, low cost deployment can extend fiber-like services to tenants in the vast majority of structures that don't meet the economic requirements for fiber optic network connection.
HFC – Cable Modem	Where CATV plant has not been upgraded for HFC functionality...	...WBA may enjoy first mover status for broadband services for small and medium businesses and residential customers.
	In commercial areas where CATV has little or no presence...	...WBA is easily and economically deployed in commercial and residential areas.
DSL	Where the subscriber is outside the 18,000 ft. radius around the central office and where DLCs are extensively employed in the network...	...WBA is easily and economically deployed regardless of central office locations or PSTN impediments.

6.0 Broadband Services Demand Forecast

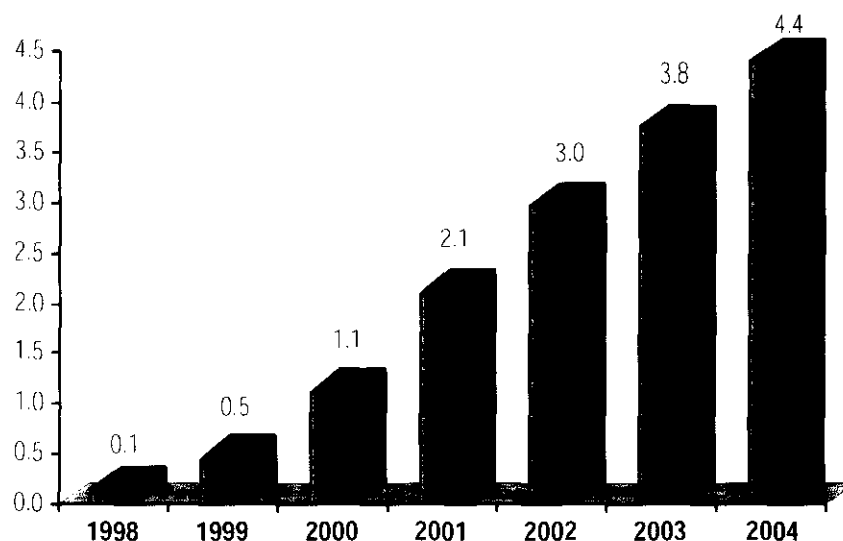
INSIGHT projects broadband telecommunications services will grow from the 600,000 access lines in place at year-end 1998 to 23.5 million access lines by the end of 2004.

Total Broadband Access Lines, 1998-2004 (Millions)



The continued growth in Internet access and the emergence of affordable service options to provide high-speed connectivity are viewed as complementing one another's growth. We believe that competition to serve this increasingly important broadband market will result in a rich selection of service alternatives for online customers. The implications of this competitive environment include better service quality, better value for customers and the likelihood that competing service providers will seek to extend broadband service into geographical areas that would otherwise have had to wait additional months or years for broadband services to reach them.

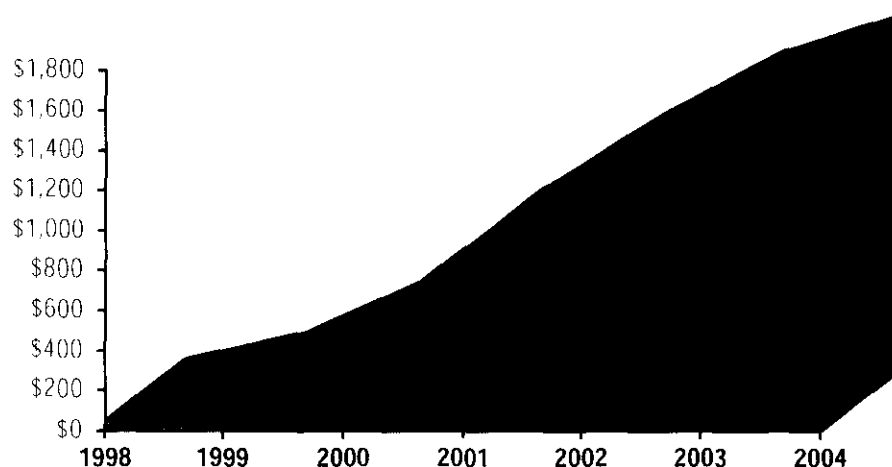
Wireless Broadband Access Lines, 1998-2004 (Millions)



Wireless fixed broadband service plays a significant role in the emerging market for broadband services. INSIGHT projects wireless fixed broadband to grow from an estimated 150,000 access lines in service in 1998 to 4.4 million access lines in 2004. This represents a compound average growth rate (CAGR) of 75.6% over the seven year forecast period. We've estimated that wireless fixed broadband will represent approximately 19% of the broadband access lines in service in 2004.

Our forecast for the revenue potential of fixed wireless broadband services is based on our view of how this entire service segment will develop. We believe that to be successful, wireless broadband options must offer service packages and service pricing which are competitive with wireline alternatives. It's our view that service revenues from wireless broadband services will approach \$1.8 billion in 2004. This represents a compound average growth rate of 84.8% through 2004.

Broadband Wireless Service Revenues, 1998-2004 (\$Millions)



7.0 Conclusions

INSIGHT Research Corp. believes that the majority of U.S. households and businesses will be Internet users by 2004. We expect that approximately 24% of these online users will have chosen broadband telecommunications services to support their online use and that the advent of broadband services will result in higher levels of satisfaction for business and residential Internet users. INSIGHT shares the views of some of the major telecommunications carriers that believe that broadband capabilities will be provided using a patchwork of service platforms to meet customers' needs. The market for broadband services will be a competitive one with a diverse selection of service providers and broadband technologies available to the customer.

INSIGHT projects that 4.4 million subscribers will choose fixed wireless broadband services by 2004, representing 19% of the total market for broadband services. Wireless technology offers an approach to broadband services that provides a rapid, flexible, inexpensive deployment plan with minimal dislocation for the community and the environment and which meets or exceeds the service capabilities of other broadband alternatives.

